

ART. VII.—*On the Structure of the Vibratile Tags
or Flame Cell in Rotifera.*

By J. SHEPHARD.

(Plates XI. and XII.).

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The somewhat doubtful tone of the remarks on the flame cell or vibratile tags of Rotifera in the second volume of the "Cambridge Natural History" led me to examine these organs in *Euchlanis dilatata* and *Brachionus pala*, species favourable to a study of the excretory system, particularly the former. Having these two forms at hand in a cultivation from dried mud, for a considerable time, there was ample opportunity to examine them, and as a result a definite conception of the structure of the organ was attained, and, being subsequently confirmed by investigations on several species, I was led to record my results in the hope of contributing towards a settlement of the vexed question as to their exact structure.

The flame cells are appendages of the lateral canals which run up each side of the body, and are regarded as the excretory organs in the Rotifera.

The outlines of the tags examined, in different aspects I found in general agreement with the description by Dr. Hartog¹ and with the descriptions and figures of various other authors. In front view the outline is more or less fan shaped, and at right angles to this it has a narrow elongated form very nearly equal in width from end to end. In the internal portions of the tags I found appearances not altogether consistent with any of the figures and descriptions to which I have had access.

Examining a specimen of *E. dilatata* when compressed so that the tags were fixed, some of them were found presenting the narrow and others the fan-like aspect. When seen in the former position, a solid plug occupied the distal end, and to it, as shown

¹ Cambridge Nat. Hist., vol. ii., p. 213.

in all the figures given, was attached what appeared as a solid and, as compared with the walls on either side, a thick flagellum, extending nearly to the point of attachment of the tag to the lateral canal, and down this apparent flagellum ran a series of undulations commencing at the attached end of the movable body and passing along to its free end.

Those in the flat aspect showed the plug at the distal end as a border of protoplasm running across; it was spongy looking, occasionally vesiculated, and with little protuberances on the outside, generally looking denser just at the point of attachment to the undulating body, and in appearance analogous to the substance of the walls of the lateral canals. As in the narrow aspect, the sides were excessively thin. Indeed in a dead animal the whole appearance was that of a hyaline fan-shaped cavity, the boundaries of which required most careful focussing to define. In a living and vigorous animal, the flickering appearance which has given rise to the term "flame cell," was very rapid, and it was difficult to determine the exact nature of the movement going on, but in animals treated with cocaine, or losing vigor through long confinement, the movement could be distinctly seen as a series of waves in some substance lying between the upper and lower surface of the tag. Through this moving substance could be focussed, and kept steadily in view, two distinctly longitudinally striated surfaces. Repeated observations on cells in various states of activity, confirmed the conclusion that these striations are on the walls of the tag and not on the undulating body. Further, the most careful scrutiny failed to show any lateral borders to the moving body other than the sides of the tag itself.

In a recently killed animal the undulatory movement could be seen to die down until it was a slight wave-like appearance, gradually narrowing until it occupied the median portion of the tag, and dying out before passing more than half way down, just as a ripple on water dies away as it recedes from the point of disturbance. Another appearance obtained from some chance views of a tag when the free end was pointing up the microscope, is shewn in Fig. 3. Here was presented an optical section showing a flattened oval with thin walls and a thicker line running between and joining the extremities.

From these appearances I conclude the tag to consist of a flattened funnel closed at one end by a protoplasmic mass, to which is attached an "undulating membrane" lying between two thin, delicately striated walls, to which it is joined on each side for its whole length, being free only at the narrow proximal end of the tag, and dividing the interior of the tag into two separate cavities or pockets.

In the references which I have been able to make to the literature of the subject, I find considerable disagreement as to the nature of the internal structure. Dr. Hartog¹ states, that: "The probable explanation of the two distinct wave appearances within the tag is that the protoplasmic plug bears on its inner face a row or tuft of long cilia hanging down into the cavity of the tag." Dr. Zelinka figures and describes² the vibratile tag of *Callidina russeola* as containing a cylindrical mass of closely agglutinated cilia, and estimates the number of such vibratory hairs. He also quotes Mœbius as having recognised the composition of the flagellum from numerous cilia. He further gives an abstract of a description of the vibratile tags in *Asplanchna amphora* by Mr. C. Rousselet, who definitely regards the vibrating structure as an "undulating membrane," and suggests that the spongy protoplasmic cap is "probably quite open enough to allow some part of the fluid of the body cavity to pass through into the tags." Dr. Hudson³ asks "Are the vibratile tags open at their free ends or are they closed. Do they contain an undulating membrane, or are their inner surfaces furred with minute cilia?" Dr. Weber⁴ describes the tags of *Hydatina senta* as a flattened bell, with a cleft at the upper part surrounded by a pad armed with short cilia, while below are two thickenings each furnished with a long cilium. He figures these cilia with undulations crossing each other. He also states that all the

¹ Cambridge Nat. Hist., vol. ii., p. 213.

² Zeit. für Wiss. Zool., vol. liii., p. 22.

³ The Rotifera, vol. ii. Appendix, p. 137.

⁴ Notes sur quelques Rotateurs des Environs de Genève, p. 39.

flame cells he has examined are of similar structure Vallentin¹ gives a figure of the flame cell of *Brachionus rubens* obtained by the section method showing a thin wall with a broad flagellum hanging from the cap.

In the face of these statements by observers of such eminence I advance my views with diffidence. However, as repeated examination of many individuals of *B. pala* and *E dilatata* and observations of a less number of each of the other species figured, as well as others not figured, such as *Anurea* sp., *Synchaeta pectinata*, *Notops brachionus*, and *Pterodina patina* all combine to corroborate the view I take, the record of these observations may be of service.

With the exception of Dr. Weber, none of the observers mentioned appear to have noted the striated nature of the walls of the tag. This he regards as due to a fine muscular network. I suggest that the conclusion as to the undulatory body being a number of waving cilia has arisen through these striations being perceived through the undulating membrane, and being confused with it. Indeed at first sight it seems obvious that cilia are present. I have already mentioned how flame cells of reduced activity show distinctly that the striation is on the walls and further that the undulating membrane is very transparent, in fact it can only be distinguished in the flat aspect by the interference with the light due to its movement. In dead animals it cannot be seen in the flat. Vallentin's figure above mentioned appears in the light of my observations as a longitudinal section taken somewhat obliquely. Without dealing separately with all the views quoted I suggest that they are all possibly due to the differing appreciations of this combination of an undulatory hyaline membrane and two striated walls which themselves in the living animal are in constant movement. Mr. Rousset's views are of course excepted, and I regret being unable to procure a copy of his paper, more particularly as I have fortunately met with *Asplanchna amphora* and find the structure to coincide with the description so far as it is given by Zelinka. I have in vain endeavoured to procure a copy of this paper and of course am unaware as to how far my

¹ Ann. and Mag. of Nat. Hist. Ser. 6, vol. viii., p. 44.

work may overlap that of Mr. Rousselet. Having arrived at a similar conclusion with regard to the undulating membrane before knowing his view and having figured a similar structure in five species it will corroborate this portion of his observations and extend it to other families. The two flagella on the outside of the tag as mentioned by him were undoubtedly present. It does not, however, appear to be necessary to assume that the spongy looking protoplasmic cap permits the passage of fluid from the body cavity into the tag as he suggests. Rather are not the thin walls instrumental in passing by osmosis the excretory fluids. From this point of view the fan-like expansion of the tag is to be explained as affording a larger surface area. Comparing the areas available for this, taking the narrow line of the caps on the one hand and the two flat sides on the other in *Asplanchnopus myrmeleo*, we should get, taking the thickness of the tag as $\frac{1}{5}$ th of its breadth and other dimensions as measured, areas in the proportion of about 11 to 1. That the fluid excreted is considerable is shown by the fact that in *A. myrmeleo* the contractile vesicle when expanded occupies about $\frac{1}{3}$ th of the body cavity and contracts at intervals of a few seconds. I counted 50 tags on one side making 100 in all. Assuming that the fluid passes through the sides, the organ in this view become an admirably adapted force pump to drive the fluid into the canals, the swing causing the crests of the undulations in the membrane to come in contact with the wall on either side. Further if flagella are in action internally they would be required to propel the fluid in the direction of their free ends, whereas in the collared and other Protozoa the action of the flagellum is to cause a current inward to the base.

Of the forms examined I refer to the accompanying figures without further comment excepting those of the tags of *A. myrmeleo* which have not to my knowledge been described. There are also some additional features of interest. Fig. 9 is a portion of a canal with tags at (a), (b) and (c) in narrow aspect and (d) in the flat. In this form there is one external flagellum about as long as the whole cell seen in the middle from the flat view and to one side side in the narrow aspect. Some cells, one shown in two aspects in fig. 12 and 13 attached to the convoluted portion of the duct at the posterior of the animal appear destitute

of flagella and to have the protoplasmic cap expanded into a vesicle. They appeared less flattened. Other cells such as Figs. 10 and 11 possessed lesser vesicles in the cap and flagella in conjunction.

The whole of the figures were drawn from a magnification of about 1000 dia. using a Leitz $\frac{1}{16}$ th semi-apochromatic oil immersion lens, and a Watson & Son's parachromatic condenser. Rigid adherence to the conditions necessary to produce a "critical image" was found necessary, and all observations were made in a flame image, daylight being unequal to bringing out the finer details.

I have to express my thanks to Professor Spencer for procuring me the literature, and to Mr. W. Stickland for assistance in reading the German and French Papers.

EXPLANATION OF FIGURES.

Euchlanis dilatata.

- Fig. 1.—Flat view of tag
,, 2.—Edge view of tag. Dimensions, length .013 mm.;
breadth .007 mm.
,, 3.—Optical section of tag seen end on (*a*) striated surfaces.
,, 4.—Portion of lateral canal.

Brachionus pala.

- ,, 5.—Flat view of tag.
,, 6.—Edge view of tag. Length .012 mm.

Hydatina senta.

- ,, 7.—Flat view of tag.
,, 8.—Edge view of tag. Length .014 mm.; breadth .01 mm.

Asplanchnopus myrmeleo.

- ,, 9.—Portion of lateral canals with tags attached in edge
view (*a*), (*b*), (*c*), and flat view (*d*). Length of
tag .009 mm.; breadth .004.
,, 10.—Flat view of tag with vesicle in cap and flagellum.

- Fig. 11.—Flat view of tag with large vesicle in cap and flagellum.
,, 12.—Flat view of tag with large vesicle and no flagellum.
,, 13.—Edge view of tag with large vesicle and no flagellum.

Asplanchna amphora.

- ,, 14.—Flat view of tag.
,, 15.—Edge view of tag. Length $\cdot 01$ mm.; breadth $\cdot 004$ mm.
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